N O T E

Yellow Sticky Cards Equipped with Light-Emitting Diodes: a Natural Enemies Compatible Management Tool for Whiteflies (Homoptera: Aleyrodidae) and other Greenhouse Vegetable Pests[1]

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Infestation by the B-biotype sweetpotato whitefly, *Bemisia tabaci* Gennadius (= *B. argentifolii* Bellows and Perring), is a major problem in vegetable and ornamental greenhouse production. Whiteflies have been known to be attracted to yellow since their orientation to this color was demonstrated by Lloyd (1921, Bull. Entomol. Res. 12: 355-359). Yellow sticky card traps are commonly used to detect and reduce populations of whiteflies in greenhouse crops. Some natural enemies of *B. tabaci* are also attracted to yellow; namely, parasitoids in the genera *Encarsia* (Simmons 1998, J. Entomol. Sci. 33: 7-14) and *Eretmocerus* (Hoelmer et al. 1998, Environ. Entomol. 27: 1039-1044; Simmons 1998) and a coccinelid predator, *Delphastus catalinae* (LeConte) (Simmons 2003, J. Entomol. Sci. 38: 481-484). Moreover, the western flower thrips, *Frankliniella occidentalis* (Pergrande), is among other insect species which have been reported to be attracted to yellow (Cho et al. 1995, J. Entomol. Sci. 30: 176-190). Although whiteflies are attracted to yellow (Lloyd 1921), they are also attracted to lime green and spring green light, with peak wavelengths in the 520 to 540 nm range of the spectrum, and to white (fluorescent) light at intensity as low as 10 lux (Chu et al. 1998, Southwestern Entomol. 23: 169-181; Chu et al. 2000, J. Econ. Entomol. 93: 1329-1337). Adult *B. tabaci* responds to a wavelength of 530 nm (El Helaly 1981, Acta Phytopathologica Academiae Scientiarum Hungaricae 16: 181-188) which is the peak wavelength emitted by the lime green LED.

The study herein was conducted to determine the potential of developing a yellow sticky card (YC) trap equipped with a light-emitting diode (LED) for detecting, monitoring, and potentially controlling *Bemisia* adults in greenhouse crops. We also report

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on the capture of a predator and *Bemisia* parasitoids, and two common greenhouse insect pest species, namely, *F. occidentalis* and *Bradysia coprophila* (Lintner), a fungus gnat.

The study was conducted using LED-modified yellow sticky card and standard yellow sticky card traps. Tests on the capture of five species of insects with the traps were conducted in a 7 × 9 m *B. tabaci*-infested greenhouse in Charleston, SC, from 02 July to 31 August 2001. Before the traps were set up, 2,300 *D. catalinae* adults and 500 *Eretmocerus* spp. adults were released in the test greenhouse during 01-28 June 2001. The *Eretmocerus* spp. were from a colony (USDA-ARS, Charleston, SC) of parasitized *B. tabaci.* The taxonomic status of the parasitoid is being reviewed by Mike Rose (Department of Entomology, Montana State University). Tests were conducted with potted 'Georgian' collard (*Brassica oleracea* var. *acephala* de Condolle) plants, and with trellised (1.1 m high) melon (*Cucumis melo* L.) plants in pots. The collard plants were at the 8 to 12 leaf stage of development at the beginning of the test. The melons consisted of 12 plant introductions and 'Top Mark,' a cultivar adapted for the southwestern United States. At the start of the experiment, the melon vines were at the flowering stage. The plants were spaced 30 cm apart on three adjacent tables, with collard on two adjacent tables and melon on the other. All plants were irrigated twice daily, but were otherwise left undisturbed throughout the experiment.

Each LED-YC trap had two lime green 45° angle LEDs (Nichia NSPPG500S, Nichia America Corp., Mountville, PA) attached. Each LED was affixed to a 2.0 cm long piece of perforated circuit board that was glued on each tip of a 7.5 cm hair clip arm. LEDs, when energized with 7.5V and 220 ohm direct current electricity, emitted 1,451 ± 15 (SE) lux measured at 4 cm from the LED. The source of electricity was from a standard 110 V wall-plug which was channeled through a home-made transformer to obtain 7.5 V direct current electricity. The hair clips with LEDs were installed on 30 cm long and 15 cm wide YC traps (450 cm^2 sticky surface on each side). The LEDs were positioned in the centers of each side of the YC traps. The traps were placed 2.4 m apart with the YC traps facing each other along the table and were 15 cm above plant terminals. One standard sticky trap and one LED-modified sticky trap were set up for each table of plants. Adult insects (*B. tabaci, Eretmocerus* spp., *F. occidentalis, B. coprophila,* and *D. catalinae*) caught on the surface of each trap were counted every 6 d for a total of 10 sampling dates. To reduce location influence, treatment locations were routinely altered within a test every 3 d. Data on maximum and minimum temperature in the greenhouse were collected and recorded every 3 d. During the test, the temperature reached a maximum of 37°C during the day and a minimum of 17°C at night. Incidence of adults caught on the sticky traps were analyzed as capture per 6 d for each crop. By crop, the data were analyzed as paired comparisons using the PROC MEANS procedure (SAS Institute 1999, version 8.2, SAS Institute, Cary, NC) in which the change in percentage of adults captured on the LED-modified YC trap was compared with the capture of adults on the standard YC trap.

In the collard and melon tests, LED-modified yellow sticky card traps caught a significantly ($P < 0.05$) greater proportion of *B. tabaci* and *B. coprophila* adults as compared with capture by the standard yellow sticky card traps (Table 1). There was no significant difference between trap types on the capture of either *F. occidentalis, Eretmocerus* spp., or *D. catalinae,* regardless of test crop. The overall capture of the

Table 1. Mean (±SE) change in the percentage of adult B-biotype *Bemisia tabaci, Frankliniella occidentalis, Bradysia coprophila, Eretmocerus* spp., and *Delphastus catalinae* caught on a 45° angle lime green light-emitting diode equipped sticky card (LED-YC) trap relative to a standard yellow sticky card (YC) trap in a greenhouse

	% change in capture by LED-YC trap (P values)	
Insect species	Collard	Melon
B. tabaci	19.8 ± 4.5(<0.001)	21.9 ± 7.9 (0.021)
F. occidentalis	6.9 ± 5.1 (0.191)	−7.2 ± 16.5(0.675)
B. coprophila	29.2 ± 8.6 (0.003)	65.0 ± 12.3(0.001)
Eretmocerus spp.	−3.0 ± 7.4 (0.689)	−32.6 ± 37.6(0.408)
D. catalinae	5.1 ± 5.8 (0.750)	21.2 ± 20.9(0.337)

Paired comparisons of LED-YC and YC traps were based on the PROC MEANS procedure (SAS Institute 1999). Across treatments, the range in the number of adults captured per trap per 6 d was 27 to 1,057 for *B. tabaci;* 8 to 1,336 for *F. occidentalis;* 0 to 15 for *B. coprophila;* 2 to 252 for *Eretmocerus* spp. and; 1 to 102 for *D. catalinae.*

various species of insects was 2 to 6 times greater for traps in the collard compared with traps in the melon.

LED-modified yellow card traps resulted in increased captures of adult *B. tabaci* and *B. coprophila* compared with standard traps, although the overall numbers were very low (0 to 15 adults per trap per 6 d) for the latter. Fungus gnats are a common nuisance in commercial greenhouses. Although high numbers of thrips were captured on both type of traps (an average of 350 adults per 6 d across trap types), the LED did not enhance the capture of this pest. This is not surprising because thrips are more attracted to blue than yellow (Yudin et al. 1987, J. Econ. Entomol. 80: 51-55). The LED-modified YC trap had no impact on the capture of the whitefly parasitoid or on the capture of the coccinelid predator as compared with the standard YC trap. This result is favorable for whitefly management which incorporates natural enemies into the management scheme. *Eretmocerus, Encarsia,* and *Delphastus* are sold commercially for use in greenhouse crop production which also use yellow sticky traps for *Bemisia* spp. monitoring and control. For whitefly management in greenhouses, standard YC traps are used to control the adults, parasitoids are released to attack the nymphal stage, and *D. catalinae* are released to feed on all stages of *Bemisia,* but mostly the immature stages. The reusable green lime LED, as used in our study, costs less than $2.00 each, and the price does not appear to be prohibitive for long-term use. The LED-YC which we have developed appears to improve *B. tabaci* management with little impact on the released parasitoids and *D. catalinae* predator.

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